WAR FOOD ADMINISTRATION

Food Production Administration

Conservation Programs Branch

Development of Ground Water for Irrigation in the North Central Valley, California.

Washington, D. C.

January 1944

Mr. Frank Hancock, Administrator
Farm Security Administration
Washington, D. C.

Dear Mr. Hancock:

This report entitled "Development of Ground Water for Irrigation in the North Central Valley of California" was prepared by Kenneth O. Bayard, Senior Water Utilization Specialist, in accordance with a request from Mr. R. W. Hollenberg, Acting Regional Director of Region IX, Farm Security Administration, for assistance in planning ground-water development under the provisions of the Water Facilities Program.

Very truly yours,

E. D. White, Chief
Conservation Programs Branch

ACKNOWLEDGEMENTS

Free use has been made of information contained in bulletins and publications of Federal and State agencies. Data were obtained from Bulletin No. 25, "State Water Plan," Bulletin No. 26, "Sacramento River Basin," and Bulletin No. 29, "San Joaquin River Basin," all of which were published by the Division of Water Resources, State of California, from the 1940 Census of Agriculture, and from U.S.G.S. Water Supply Paper No. 495, "Geology and Ground Water Resources, Sacramento Valley, California." Descriptions of the soils and soil classification were obtained from University of California Bulletin No. 599, "A Rating of California Soils."

Acknowledgement is made of the assistance received from the Regional Office of the Farm Security Administration at San Francisco, California and especially from Mr. Paul H. Watson, Associate Engineer, who helped in the field investigation and provided data for use in this report.

PURPOSE AND SCOPE

The purpose of this report is to provide the Farm Security Administration guidance in developing, under the provisions of the Water Facilities Act, ground water for irrigation of lands in the North Central Valley. The scope of the report is limited to a description and an analysis of the physical conditions of the Valley as they pertain to ground-water development. The discussion of the agricultural, geological and ground-water conditions of the North Central Valley is stated in general terms with more detailed information of local features being presented in the analysis of conditions in the specific water-supply areas or subareas which combine to make up the total area covered in this report. Some areas have been discussed only generally and some not at all, whereas others have been dealt with in greater detail; the reason for this approach is that, although ground water is present throughout the Valley, the demands for its development by Farm Security Administration clients as a supply of irrigation water are restricted at this time to only a few localities. In other words, areas where an interest in using ground water for irrigation has been evidenced by requests for assistance in drilling wells have been treated in more detail.

RECOMMENDATION

It is recommended that the Administrator of the Farm Security Administration approve the North Central Valley for operations under the Water Facilities Program, and that authorization be given for processing loans of Farm Security Administration clients who wish to borrow money for drilling and equipping wells for irrigation. With the exception of the Clear Lake area, loans should be granted to those clients who farm lands on the Valley floor where ground-water supplies are available for development. The shaded area on the accompanying map shows roughly the area within which it is reasonably safe to expect good supplies of ground water.

To assure a long and profitable use of the facility, wells should be cased to the bottom of the well as the alluvial fill of the Valley will ultimately cave without such support. On farm lands lying near the foothills, sites must be carefully selected and when possible should be near the stream courses and washes. It will help field technicians of the Farm Security Administration, who are assisting the farmers, to obtain as much information locally about neighboring wells to guide them in determining the site, the size of hole and casing, the drilling depth, the pump setting and the size and capacity of the pump.

NORTH CENTRAL VALLEY

I

Description of the Area

Location

The area discussed in this report consists of the agricultural land of that portion of the Great Central Valley of California lying between Redding to the north and the Stanislaus-Merced county line to the south. For the sake of convenience the area has been designated in this report as "The North Central Valley" although it is recognized that the valley lands lying south of the Sacramento-San Joaquin Delta in San Joaquin County should be properly considered as part of the South Central Valley. Thus the drainage area covered by this report includes the main stream and tributaries of the middle and lower Sacramento River and of the lower San Joaquin River. The discussion is further limited primarily to the valley lands, delineated on the accompanying map by the shaded portions, in which ground water is generally available for development.

The Sacramento Valley contains about 4¼ million acres of irrigable land of which about 2½ million acres occupy the valley floor, the remainder being found in the foothill area, the mountain valleys, and the Delta area. Roughly, another 700,000 acres of irrigable land in the lower San Joaquin Basin are located in San Joaquin and Stanislaus Counties. Much of the land in the Valley is dry-farmed, particularly along the margins of the Valley near the foothills; the irrigated land as a rule lies at lower elevations along the principal stream courses.

Climate

The climate of the Central Valley is moderate with hot summers and mild winters. The frost-free growing season ranges over the Valley from approximately 230 to 300 days. Precipitation is light in the warm season from April to September, ranging from one or two inches in the south to four inches in Tehama County. The average annual precipitation is about 30 inches or more near Red Bluff and between 10 and 15 inches in Stanislaus County.

Geology

The North Central Valley is an alluvial plain filling a great structural trough and extending from Red Bluff some 200 miles south to Stanislaus County. The Cascade Range and Sierra Nevadas bound it on the east and the Coast Range on the west, elevations of the valley floor ranging from 300 feet above sea level to slightly below sea level in the Suisun Bay Area. The most prominent topographic feature within the Valley is the Marysville Buttes, an ancient volcanic vent, which lie northwest of Marysville and rise to an altitude of approximately 2,100 feet above sea level.

The alluvial plain consists of five physiographic units:

(1) The old Valley fill is found on the uplands or higher lying areas along the margins of the Valley. It is composed of older indurated alluvium which because of surface run-off has developed definite drainage patterns.

(2) The modern alluvium of the low plains and alluvial fans extends from the inner margins of the uplands to the trough

of the Valley. It is composed of alluvial fans of the major and minor streams.

(3) The modern flood-plain ridges of the Sacramento and Feather Rivers consist of broad alluvial flood-plain deposits extending through the Valley trough.

(4) The overflow or flood-basin deposits lie on both sides of the flood-plain ridges and are deposited by flood waters backed up by various ridges during the high-water periods.

(5) The Delta of the Sacramento-San Joaquin Rivers occupies a portion of the area at the junction of the two rivers. It existed originally as a tule swamp but has been reclaimed to some degree.

The occurrence of ground water and its replacement and recovery are largely controlled by the above physiographic distinctions in the type of sedimentary deposits. Throughout the Valley the sediments are deep, borings of 2,000 feet having failed to penetrate to bed rock.

Soils

The soils of the Valley are mainly old valley fill and recent alluvial-fan and alluvial material. In the foothills along the borders of the Valley, the soils are residual materials from the disintegration and weathering in place of consolidated rocks. Some wind-deposited material is found in the Sacramento Valley but most of this type of soil is found farther south in the San Joaquin Valley. A number of soils series have been classified by the Bureau of Soils of the U.S.D.A. An excellent reference for general guidance is "A Rating of California

Soils," University of California Bulletin No. 599, by Walter W. Weir and R. Earl Storie.

Land Classification

Rated on the basis of its irrigability, grade of soil and freedom from alkaline salts, about 48 percent of the land on the Valley floor is considered to be Class 1 land and about 25 percent of the total is placed in Class 2. Lands in the latter grouping are usually held in larger holdings and are used more generally for pasture. The remaining 27 percent of the land consists of Class 3 to 5 land which, except for some rice growing on Class 3 land, is used mainly for gun clubs and pasture.

Hydrology

Surface Water Supply - The Sacramento Basin which occupies approximately 17 percent of the total area of California, yields about 35 percent of the total water supply from the entire mountainous area of the State. The seasonal runoff estimated for a 40-year period totals about 25 million acre-feet, although a ten-year mean for the period 1919-29 indicated the flow to amount to approximately 18 million acre-feet. In contrast the San Joaquin River Basin occupies approximately 21 percent of the total area of California and yields only 17 percent of the water supply in the mountainous area of the State. The seasonal runoff of the San Joaquin River Basin for a 40-year period is estimated to total about 12 million acre-feet, but for the period 1919-29 the mean flow was 8.5 million acre-feet.

All this surface water is not available for irrigation since part of it must be allowed to flow for recreational, hydroelectric power and navigational uses. With the construction of the Shasta Dam, Friant Dam and others proposed under the State Water Plan the flow of streams in the Central Valley will be regulated so that more complete use can be made of the supply available for irrigation which, particularly in the San Joaquin Valley, is inadequate for present needs.

Ground Water Supply - Ground water of uniformly good quality is found at varying depths throughout the floor of the Central Valley lying naturally closer to the surface near the principal stream beds and at greater depths along the foothills. The accompanying map shows the approximate boundaries of the ground-water area. The depth to water ranges from two or three feet below the surface in the trough of the Valley to approximately 50 feet below the surface along the margins of the alluvium. The average pumping lift of 9,400 irrigation wells in 14 counties of the Valley is about 42 feet, ranging from average lifts of 92 and 59 feet in Contra Costa and Colusa Counties, respectively, to 23 feet in Shasta County.

According to a statement appearing in the State Water Plan, 1/ approximately three million acre-feet of water can be stored in underground basins in the Sacramento Valley and another three million acre-feet in the lower San Joaquin Valley. This water can be put to good use in many areas in the Valley where the aquifer is sufficiently permeable to provide an adequate supply for irrigation and where pumping lifts are not too great to preclude economical use and competition with gravity

1/ P. 99, Bulletin 25, "State Water Plan," Division of Water Resources, California Department of Public Works, 1930.

surface supplies. To quote the Division of Water Resources [1], "If underground storage were operated in conjunction with surface storage, a greater use could be made of the runoffs of tributary streams since some of the water which would be wasted into the ocean in the winter season could be stored in these underground reservoirs and used in seasons or cycles of low surface runoff."

However, it must be recognized that in some localities where gravity distribution systems are in operation and in others where the permeability of the alluvium is too low to provide adequate water for irrigation, it is inadvisable to drill wells for irrigation purposes. Wells for stock and farmstead purposes can be drilled practically throughout the Valley floor.

Present Use of Ground Water

About 65 percent of the agricultural lands in the Sacramento River Basin are irrigated and about 71 percent of the lower San Joaquin Valley. An idea of the relative proportion of land being irrigated from ground-water sources is obtained from a survey made in 1929 which found that of the 719,000 acres of irrigated land in the Sacramento Valley under study, 203,000 acres or 28 percent were irrigated by pumping ground water, the rest receiving its water from surface supplies. In the North San Joaquin Valley most of the land is irrigated from surface water stored in dams on the Merced, Tuolomne and Stanislaus Rivers. Here, in general, pumping from wells is limited to drainage but some of the water thus obtained is used for irrigation.

1/ P. 36, Bulletin 26, "Sacramento River Basin," Division of Water Resources, California Department of Public Works, 1931.

About 20 flowing wells and 9,400 pumped wells are delivering water for irrigation purposes in the North Central Valley. The extent of ground-water use by counties is indicated in Table 1.

Table 1.

County	Irrigation Wells 1/ Number of Wells Flowing	Number of Wells Pumped	Average Pumping Lift (feet)
Shasta	-	38	23
Tehama	1	558	34
Butte	3	548	32
Sutter	-	1,162	34
Yuba	-	198	31
Glenn	1	279	31
Colusa	-	84	59
Lake	2	133	33
Yolo	-	648	39
Sacramento	-	1,783	38
Solano	-	494	56
San Joaquin	1	3,072	35
Stanislaus	5	224	57
Contra Costa	-	181	92
Total	20	9,402	42

1/ Data from 1940 U. S. Census of Agriculture

By far the greater proportion of irrigation wells are located near the Delta area, approximately one-half of the total being found in San Joaquin and Sacramento Counties. The next heaviest concentration of irrigation wells is found in Sutter and Yolo Counties, while the lowest number is found in Colusa County where good supplies of water for irrigation are obtained by diversion from the Sacramento River.

The net use of water in the North Central Valley varies widely according to the location of the lands irrigated and the types of crops grown. The average net use is about 2¼ acre-feet per acre for a full supply and 1 acre-feet per acre or less for a late-season supplemental supply.

Crops

The irrigated crops grown in the North Central Valley listed in order of the relative acreage planted consist of deciduous orchards, rice, truck crops, field crops, alfalfa and sudan grass, grape vines, citrus and olives, and cotton. Grain is the principal non-irrigated crop. The acreage planted to grain far exceeds the acreage of any one of the irrigated crops, accounting for over 50 percent of the total planted acreage. Pasture for livestock is the most important use of the lower grade lands.

Livestock

Cattle, sheep, hogs and goats are raised in extensive numbers in the Valley. According to the 1940 Census of Agriculture, the number of cattle in 14 counties of the Valley totaled approximately 415,000, of which slightly more than 168,000 were dairy cows, two years of age or over, the remainder being dairy heifers and beef cattle. Stanislaus County was first and San Joaquin County second in both the number of cattle and the number of milch cows. Of the total of 814,500 sheep in the Valley, Tehama County led with 138,800 head and Glenn County was second with 122,100. The number of hogs totaled 158,900, Colusa County leading with 25,900 and San Joaquin second with 19,200. Goats, both the Angora wool and milch types, totaled 17,400 in number, Tehama and Shasta Counties occupying first and second places with 7,500 and 3,500 head respectively. Poultry raising is also an important activity in the Valley.

II

Recommended Ground-Water Development

The development of ground water for irrigation is recommended for lands lying on the Valley floor and in the Clear Lake Area. The following discussion presents data on ground-water conditions for specific areas with some suggestions for proper development of the facilities.

Middle Sacramento River Valley (B2b)

The Middle Sacramento Valley which extends from the Kennett Reservoir to the junction of the Feather River includes the tributary drainages of Cottonwood Creek (B2b1), Battle Creek (B2b2), Stony Creek (B2b3), Butte Creek (B2b4), as well as other minor tributaries (B2b5).

Anderson Valley (Cottonwood and Battle Creeks), Shasta County

The irrigated land south of Redding in Shasta County derives most of its irrigation water from surface supplies diverted from the Sacramento River by the Anderson Cottonwood Irrigation District, and by the Happy Valley Water Company from Clear and Cottonwood Creeks. The use of ground-water is limited in scope as indicated by the fact that, according to the 1940 Census of Agriculture, there were only 45 irrigation wells in Shasta County. Seven of these are flowing wells, the remaining 38 being under pump. Along the Valley floor, where the Class 1, 2 and 3 lands are irrigated, ground water is shallow ranging in depth from about 10 to 25 feet below the surface. Pumping lifts for the county average about 23 feet. Alfalfa, fruit and general farm crops are grown under irrigation and grain and hay without irrigation. Pasture, for which the Class 4 soils on the

terraces and in the foothills are utilized, provide feed for 34,000 cattle and 15,000 sheep raised in Shasta County.

It is not anticipated that many requests for drilling irrigation wells will come from this locality but such requests can be given favorable consideration. Caution must be exercised, if wells are drilled, to locate them on the Valley floor and near stream courses if possible, as the prospects of obtaining water for irrigation purposes are not so good on the rolling terraces above the Valley floor. Moreover, there is some question that the Class 4 lands on the terraces will be profitably irrigated.

Red Bluff - Corning Area, Tehama County

The Class 1 and 2 soils of this area are used extensively for irrigating fruit, alfalfa and other irrigated crops and the lower class soils for grain or pasture. The better soils lie east and south of Red Bluff on both sides of the Sacramento River. Sheep raising is important in this county, there being approximately 139,000 head in 1940. The number of cattle amounted to about 30,000 head of which 6,300 were dairy stock two years or older; hogs, 12,600 in number, and goats, 7,500 in number, are raised in this county.

Five organizations consisting of three irrigation districts, one public utility water company, and one mutual water company, provide water for irrigation in Tehama County. Four of them divert surface water from the Sacramento River, Deer Creek, Mill Creek and Antelope Creek, while one district is pumping ground water. Ground-water conditions on the Valley floor are favorable for drilling irrigation wells, the water lying

at depths from approximately 10 to 65 feet. There are about 560 irrigation wells in Tehama County from 6 to 12 inches in diameter. Those near Red Bluff range in depth from 35 to 250 feet with the depth to water at 25 to 65 feet, while those in the Corning area are from 60 to 275 feet deep with the water levels at 10 to 40 feet below the ground surface. The average pumping lift for the county is about 35 feet, the lifts at Corning being slightly less than those around Red Bluff. The log of the Brownfield well south of Corning, and west of the Sacramento River, appears below. This well was drilled by the Farm Security Administration under the provisions of the Water Facilities Program.

Log of Joseph H. Brownfield Well

0 to 13 feet	Gravelly soil
13 to 28 feet	Clay and gravel, some hardpan
28 to 31 feet	Blue gravel
31 to 32 feet	Clay
32 to 38 feet	Water-bearing gravel-good-perforated casing
38 to 58 feet	Clay, some gravel
58 to 66 feet	Clay
66 to 77 feet	Clay and gravel
77 to 125 feet	Clay
125 to 135 feet	Water-bearing gravel-good-perforated casing
135 to 140 feet	Cemented gravel
140 to 143 feet	Water-bearing gravel-good-perforated casing
143 to 149 feet	Cemented gravel
149 to 152 feet	Clay

The well was cased to a depth of 150 feet with 10-inch 12-gauge red stovepipe casing with riveted joints. The water stood at 30 feet and when pumped at the rate of 375 gallons per minute drew down 25 feet to 55 feet, the yield being 15 gallons per minute per foot of drawdown.

Applications for assistance in developing ground water may be expected in the Red Bluff-Corning area. Most applications will probably come from owners or operators of land between the foothills south of

Red Bluff. Assistance should be given to those applicants who are farming the better lands on the Valley floor and caution must be exercised in granting loans for the drilling of wells on the terraces and bench lands, as it is doubtful if the poorer soils will bring in sufficient returns to warrant irrigation. It is recommended that, depending upon the sizes that can be procured, at least 10-or 12-inch casing be used. Wells should be cased to the bottom of the hole to prevent any possibility of the entry of sand or silt into the well.

Chico Area (Butte Creek), Butte County

The Chico area in northwestern Butte County extends from the Sacramento River eastward to the foothills. The Class 1 and 2 soils are used extensively for irrigating deciduous fruits and alfalfa and for dry-farming grain. The heavier soils in Classes 3 and 4, those composed of clay loam and clay adobe, are used for growing rice and the poorer soils are used mainly for pasturing cattle, sheep and hogs.

There are eight organizations in Butte County providing surface water for irrigation. Five are irrigation districts, two are public utility water companies, and one is a mutual water company. Surface waters are diverted from both the Feather River and Butte Creek. About 550 wells are providing ground water for irrigation of lands in Butte County, the 1940 Census of Irrigation indicating that three are flowing wells and the rest pumped wells. The average depth to ground water in this area is about 15 feet, the depth being less near the Sacramento River and Butte Creek and deeper near the foothills. The average pumping lift for the county is about 32 feet.

The number of requests that may arise for assistance in developing ground-water supplies in the Chico area is not known. At the time the field investigation was made, the Farm Security Administration had received no applications from its clients in this locality. If the Farm Security Administration is asked to drill wells in this area such work can be safely undertaken and is so recommended. The facts concerning depth to water, drawdown, specific yield and pumping lifts of neighboring wells in the vicinity of the proposed well should be ascertained to serve as a guide to Farm Security Administration technicians in the field as to the possibility of obtaining adequate supplies for irrigation and as to the benefits to be derived from such an installation. It is inadvisable to drill wells for irrigating the poorer soils on the terraces and upland areas as the returns from such investments are likely to be inadequate owing to the limited yields, the greater pumping lifts and the undeveloped condition of land for distributing the water.

Colusa Area (Stony Creek), Glenn and Colusa Counties

The Colusa area in Glenn and Colusa Counties is located on the west side of the Valley between the Coast Range foothills and the Sacramento River. It includes the tributary drainage of Stony Creek and several minor streams. The better drained and lighter textured soils in the area are planted to dry-farmed barley and wheat or to irrigated alfalfa, citrus and deciduous fruits, and general farm crops. The heavier and poorly drained soils are used to raise rice and for pasture. Sheep, cattle, both dairy and beef, and hogs are raised extensively in these two counties. The total number of each amount to over 202,000 head of sheep, 30,000 head of cattle, and 43,700 hogs.

The principal source of irrigation water in the Colusa area is by diversion from the Sacramento River. There are seven irrigation districts, six of them organized under State law to divert water from the Sacramento River and one federal project, the Bureau of Reclamation Orland Project, using water stored in two reservoirs on Stony Creek. One public utility water company provides water from the Feather River and four mutual water companies are in operation, three of them diverting from the Sacramento River and one pumping ground water. The two counties have a total of about 365 irrigation wells of which only one is a flowing well. In general, water levels are higher in Glenn County than in Colusa County, ranging from an average of about 18 feet in the former to about 25 feet in the latter. The usual irrigation well has 12-inch casing, the depth of well averaging around 120 feet although the depths range from 50 feet to 300 feet. The average pumping lift is about 30 feet in Glenn County and about 60 feet in Colusa County. The data just cited indicate that water levels near the foothills in Glenn County lie at higher levels than they do in Colusa County. Also the higher pumping lifts in Colusa County indicate that the sands and gravels encountered are tighter or less permeable than those encountered in Glenn County. Moreover it appears that some wells in Colusa County have been drilled to supply the terrace land which lies too high above the canals to be served by them.

The number of applications that may be received by the Farm Security Administration for assistance in ground-water development in this area is a matter of conjecture as none was on hand at the time field investigation was made. However, such development can be safely undertaken and is so recommended. Field personnel engaged in locating wells for Farm Security

Administration clients should obtain information locally on the depths of holes, static water level, drawdown, and specific yield of nearby wells so as to guide them in proper selection of the site of the proposed well and the probable size and capacity of the pumping equipment.[1/]

Lower Sacramento River Valley (B2c)

The Lower Sacramento Valley which extends from the junction of the Feather River to Suisun Bay includes the drainages of the Feather River (B2c1), Cache Creek (B2c2), American River (B2c3), and minor tributaries (B3c4) such as Putah Creek, the Delta area and Suisun Bay streams.

Marysville-Yuba City Area (Feather River), Yuba and Sutter Counties

The Marysville-Yuba City area in Yuba and Sutter Counties lies east of the Sacramento River and extends to the foothills of the Sierra Nevadas. A wide variety of crops are grown in this area, most of them with the exception of grain being irrigated. In order of acreage planted, the crops consist of grain, deciduous fruits, mostly peaches for canning, field crops, rice, grapes, truck crops, alfalfa and sudan grass and small acreages of cotton, citrus and olives. The poorer lands are used for pasturing livestock of which, in 1940, there were about 69,500 sheep, 21,500 cattle including 9,000 dairy stock, and 11,000 hogs.

Surface water for irrigation is supplied by 15 organizations in these two counties, three of which are irrigation districts, two public

1/ Excellent information may be obtained from "Design and Operation of Small Pumping Plants," by Carl Rohwer. U.S.D.A. Circular No. 678, October 1943.

utility water companies, and 10 mutual water companies. Five obtained their water from the Sacramento River, five from the Feather River, three from the Yuba, one from Bear River and one from Dry Creek. Extensive use is made of ground water mainly in Sutter County which has about 1,160 irrigation wells. Yuba County has only 200 or so wells. The average depth of wells is around 60 feet, the range being from approximately 20 to 145 feet. In Sutter County ground-water levels range from 5 feet near the streams to 30 feet, averaging about 12 feet. In Yuba County the static water level is slightly lower and ranges from 10 to 30 feet below the ground surface, the average depth being about 20 feet. Pumping lifts average 34 feet in Sutter County and 31 feet in Yuba County. The log of the Donaldson well located about three miles west and seven miles south of Yuba City in Sutter County is presented to indicate representative ground-water conditions. This well was drilled by Farm Security Administration under provisions of the Water Facilities Act.

Log of E. S. Donaldson Well

0 to 4 feet	Topsoil
4 to 10 feet	Brown clay
10 to 12 feet	Brown sand
12 to 40 feet	Yellow clay
40 to 41 feet	Sand
41 to 60 feet	Blue sandy clay
60 to 85 feet	Blue clay
85 to 90 feet	Blue sand
90 to 115 feet	Blue clay
115 to 125 feet	Soft clay and sand
125 to 133 feet	Soft clay
133 to 145 feet	Tight blue clay

This well, 14 inches in diameter, was cased only to a depth of 69 feet with 14-inch, double, red-steel casing and, as a result of not carrying the casing below the principal water-bearing sand (85 to 90 feet depth),

sanded up with blue sand to the depth of 90 feet. After an 18-hour pumping text "Excessive amounts of sand" 1/ were no longer pumped but the sand had risen 18 feet in the well to a depth of 72 feet. The static water level in the well was 11 feet, and when pumping at the rate of 1,500 gallons per minute drewdown 30 feet to the 41-foot level. The specific yield therefore on the basis of this test was 50 gallons per minute per foot of drawdown.

Ground water in quantities sufficient for irrigation may be safely developed on the Valley floor in this area and it is recommended that applications by Farm Security Administration clients for assistance in drilling wells be processed. However, it must be pointed out that when drilling in alluvial fill such as that encountered in Central Valley, the well casing should be carried below the aquifers encountered. Wells should be cased to their full depth and the casing should be perforated at the level of the water-bearing sands and gravels. Failure to case the Donaldson well to the bottom may have shortened the effective life of this source of ground water for irrigation use. After a relatively short number of years of pumping this well, the amount of fine clay particles drawn into the well by the movement of water and deposited in the sand at the bottom of the hole may become so great as to impede the flow of water through the sand and thus create a seal. Decrease in the yield of water may make the present pump too inefficient for irrigation use with the result that the benefits to be derived from the present plant may not be realized to their fullest extent; irrigation from this well may have to be

1/ Quoted from Report of Pump Test.

abandoned and the well used for stock or domestic purposes. It is realized that well casing at the present time is somewhat difficult to obtain, and that its cost at wartime prices creates the desire to use as little casing as can be "gotten away with", but in the long run, skimping of material so necessary to the long life and efficient operation of a facility is not sound from the standpoint of engineering practice or of economics.

Woodland Area (Cache Creek), Yolo County

The Woodland area is located west of the Sacramento River in Yolo County. Grain, grapes and deciduous fruits are grown extensively on the better soils of this area. Rice is grown on the heavy-textured soils where water is available for irrigation. Grain and grain hay are grown throughout the area. The Woodland area derives its water supply principally from Cache Creek both by use of surface water stored in Clear Lake through service provided by the Clear Lake Water Company, a public utility, and by pumping ground water. A mile or so west of Woodland in the Esparto-Madison District ground water is found at an average depth of approximately 12 feet. At Woodland the depth to ground water is slightly greater, averaging about 18 feet. The average over the county is about 15 feet. The wells are usually 12-inch holes ranging in depth from 50 to 150 feet in the Esparto-Madison District and from 35 to 210 feet in the Woodland area, the average well in the county measuring around 70 to 75 feet deep. There are about 650 wells in the county, the average lift being about 40 feet. Ground water is available for development in this area and it is recommended that the Farm Security Administration clients who farm land

on the Valley floor be assisted when applications are submitted for assistance in drilling wells. Again it must be repeated that a survey of wells in the neighboring area should be made to obtain information pertinent to ground-water conditions at or near the site of the proposed well.

Clear Lake Area (Upper Cache Creek), Lake County

The Clear Lake area as shown on the accompanying map is the only area discussed in this report that does not occupy the Valley floor of the Sacramento. It is located in the central portion of Lake County which lies in the Coast Range about 70 miles north of San Francisco Bay and midway between the Ocean and the Sacramento Valley. The elevation of Clear Lake is about 1,300 feet above sea level. The agricultural lands rise another 200 feet in elevation. Surrounding the Lake, particularly to the northwest and the southwest, are flat valley lands which are made up of recent alluvial soils with which are intermingled slightly older and more weathered soils. Drainage is an important factor in the soils adjacent to the Lake. Clear Lake is noted for its pears which are largely grown on the recent to slightly weathered alluvial soils. Alfalfa, hops, walnuts, prunes and vegetables such as lima beans, string beans, carrots and beets are grown on these soils. Grapes, walnuts and grain, mostly barley, are grown on the hilly, rolling residual soils. According to the 1940 Census of Agriculture there were 141 irrigated farms in Lake County averaging about 400 acres in size. Only 3,280 acres, or 6 percent of the total acreage, were actually irrigated, this despite the fact that most of the 28 inches of annual rainfall occurs during the winter months. Of the irrigated acreage, 3,130 acres were harvested crop land and 150 acres were irrigated

pasture. About 200 acres of the irrigated land lie north of Clear Lake, the remainder lying to the west and south.

The source of surface water supply north and west of the lake originates in Clover Creek, Middle Creek and Scott Creek, and that for the area south of the lake originates in Cole, Adobe, Kelsey, Cold and Soda Creeks. No storage is provided, however, and what surface water is used for irrigation is secured by direct diversion. Ground water is obtained from the 135 irrigation wells located in Lake County, two of which are flowing wells. In the vicinity of the town of Upper Lake, where artesian flow has been obtained, the wells are 6 to 8 inches in diameter and drilled to depths of 80 to 90 feet. A typical log of a well in this vicinity is presented:

Log of Well Owned by Clear Lake Cannery

0 to 6 feet	Topsoil
6 to 9 feet	Fine gravel
9 to 19 feet	Alternating clay and fine gravel
19 to 29 feet	Clay or shale
29 to 69 feet	Grayish-brown sandy loam
69 to 79 feet	Gravel

It was indicated during field investigation that this well flows with a head of 8 feet above the ground surface, but usually in September the artesian flow subsides to some extent. One 6-inch well powered with a five horsepower motor turning a centrifugal pump set at 16 feet delivered about 500 gallons per minute. According to the 1940 Census the average pumping lift for wells in Lake County, most of which are west and south of Clear Lake, was 33 feet.

At the time the field investigation was made in this area (December, 1943), one Farm Security Administration client had applied for assistance

in drilling a well to irrigate pasture. Investigation shows that this land, which is located in Clover Valley, is underlain by ground water at a depth of about 15 feet. It is recommended that this application, and any others originating in the Clear Lake area, be processed. It is anticipated that most applications in the Clear Lake area will come from farmers operating west and south of the Lake. Artesian flow may be expected in the Sections 12, 13 and 14, T 15 N, R 10 W, (M. D. B. & M.).

An excellent opportunity is afforded here to the Farm Security Administration in promoting irrigation and increasing the production of crops essential during the wartime emergency. Conversation with local cannery officials revealed that the cannery could process greater quantities of vegetables than they have. For instance, in 1943, the cannery packed 314 tons of string beans and could have handled three times that amount. In the same year they packed 263 tons of lima beans and could have processed 125 tons more. The beet crop failed in 1943 but the cannery can pack about 340 tons in addition to 750 tons of July carrots and 750 tons of October carrots. The average net return per acre to vegetable growers in 1943 amounted to approximately $200 an acre with carrots selling at $22 a ton, beets at $21 a ton, shelled lima beans at $105 a ton, and string beans at $110. If farmers could be encouraged to plant two acres of mixed vegetables, the net profit on their operation would be in the neighborhood of $400. Full use of the facilities offered by the cannery might be attained if the Water Facilities Program is directed toward the policy of lending money for irrigation facilities providing the farmers plant one or two acres of vegetables. The increased production of these crops, which have been determined as vital to the war effort, would be appreciable.

Sacramento Area (American River), Sacramento County

The Sacramento area lies east of the Sacramento River at the junction of the American River. The better soils, Classes 1 and 2, are found along the stream courses of the Sacramento, American and Cosumnes Rivers. By far the greater portion of the land in the county is classed as Grade 3 or lower. The principal crops in the order of the acreage devoted to each one are: grain, truck crops, deciduous fruits, grapes, field crops, alfalfa and sudan grass, rice, citrus fruits and olives. The poorer lands provide pasture for 28,000 cattle of which approximately 50 percent are dairy cows, over 17,000 sheep and 8,300 hogs. Three irrigation districts, two public utility water companies and five mutual water companies provide surface water for irrigation, four of them taking water from the Sacramento River and six from the American River. Sacramento County is first in the number of irrigation wells in the Sacramento Valley with a total of about 1,800, having an average pumping lift of about 38 feet. Ground-water levels range from 12 to 80 feet below the ground surface, the average being about 20 feet in the area south of the city of Sacramento. The wells are 8 to 12 inches in diameter and are from 35 to 265 feet deep, the average being about 140 to 150 feet deep.

At the time field investigation was made, no applications for assistance in developing ground water were on hand, hence the extent to which applications may be submitted in the future cannot be predicted. It is recommended that applications submitted by farmers operating on the Valley floor be processed, as ground water is available for irrigation use. The precautionary measures indicated in the earlier discussions of areas in the Valley should be observed.

Davis-Dixon Area (Putah Creek), Northern Solano County

The Davis-Dixon area which includes Vaca and Pleasant Valleys covers the northern half of Solano County extending from the Vaca Mountains eastward to the Sacramento River. A large tract of Class 1 and 2 soils extends along the Sacramento River. Another tract of similar soils near Putah Creek extends from the foothills to a line running roughly northeast to southwest connecting the two towns of Davis and Dixon. The foothills and intervening lands between the two tracts of good land consist of soils graded as Classes 3 and 4. Most of the irrigated land lies in the southeastern part of the county along the Sacramento River, with smaller tracts along the Putah Creek near Davis, and near Dixon. The principal crops in the order of acreage planted to each are: grain, deciduous fruits, truck crops, alfalfa and sudan grass and field crops. The poorer lands provide pasture for 103,000 sheep, 37,500 cattle, including 6,500 dairy cows, and 7,600 hogs. Ground water is pumped in the vicinity of Davis and Dixon and is the main source of water for irrigation use. Approximately 500 irrigation wells are located in the county ranging from 60 to 200 feet deep, the average being about 100 feet. The static water level ranges from 10 to 45 feet below the ground surface, averaging about 20 feet. The average pumping lift for the county in 1940 was about 56 feet.

In December of 1943, the Farm Security Administration had four applications for drilling and equipping irrigation wells from clients living in the vicinity of Vacaville and Elmira southwest of Dixon. These wells are to be drilled to provide water for irrigating alfalfa, Ladino clover, garden crops and for stock and farmstead use. No applications had been

submitted by December from the area around Davis and it is doubtful if any will be received or processed. Applications in the vicinity of Dixon and Vacaville should be approved and it is recommended that this be done. Field technicians should study the performance of irrigation wells in the vicinity of proposed sites of new wells as it is suspected that in some parts of the area near Dixon, ground-water conditions are not too favorable for extensive drilling; yields in some instances may be unsatisfactory because of tight aquifers. It is suggested, therefore, that before drilling, especially near Davis, more exact information on local ground-water conditions be obtained from the staff of irrigation engineers at the Experiment Station at Davis.

Fairfield Area (Suisun Creek), Southern Solano County

Prunes, peaches, apricots and pears are grown extensively near Fairfield in Southern Solano County. Alfalfa, Ladino clover, asparagus, beets, beans, potatoes and other crops are also produced here. Ground water in the amount of one-half to one acre-foot per acre is pumped in August and September to supplement rainfall. Wells range from 120 to 180 feet deep with lifts of 50 feet or more, the average lift for the Suisun Bay area being around 70 feet.

It is recommended that the applications for assistance in developing of ground water in this area be approved. The interest in this development is indicated by the fact that, when field investigation was conducted, three requests were on hand from farmers in the vicinity of Fairfield and that more were forthcoming. The prospects of obtaining an adequate supply of ground water are much better in the deeper valley soils

which show good drainage, and not so favorable in the narrow fingering valleys where the soils are shallow and the rock strata are close to the surface of the ground. Wells should not be drilled too near the rocky hillsides but should be located near the stream courses.

Lower San Joaquin Valley (B3b)

The Lower San Joaquin Valley includes the drainages of the San Joaquin River above Firebaugh (B3b1), Fresno River (B3b2), Merced River (B3b3), Tuolomne River (B3b4), Stanislaus River (B3b5), Calaveras River (B3b6), Mokelumne River (B3b7), and the western Valley and minor tributaries to Suisun Bay (B3b8). This report, however, discusses only that portion of the Lower Valley in Stanislaus, San Joaquin and Contra Costa Counties.

Stockton-Modesto Area (Tuolomne, Stanislaus, Calaveras and Mokelumne Rivers), Stanislaus, San Joaquin and Contra Costa Counties

The Stockton-Modesto area includes the Valley land lying between the foothills on both sides of the San Joaquin River. Extensive and continuous tracts of Class 1 and 2 lands are found on both sides of the San Joaquin River and in the valleys of the Stanislaus, Calaveras and Mokelumne Rivers. In general, soils of lesser grades are found on the terraces between the tributary stream valleys, and in the foothills, although some Class 3 and 4 lands are present on the Valley floor. Truck crops, such as asparagus, carrots and onions, beets, grapes, deciduous fruits, alfalfa and beans are irrigated on the better lands. Grain and hay occupy large areas of the dry-farmed soils of intermediate grade and

the rougher soils are used for pasturing some 194,000 cattle, of which about 100,000 are dairy cows, 123,000 sheep and 31,200 hogs. Surface water, stored in dams on the Merced, Tuolomne and Stanislaus Rivers, is the principal source of supply for irrigation, although there are more than 3,300 wells in the area, most of which were developed for drainage. Water obtained from drainage wells is often reused for irrigation. Depth to ground water is from 5 to 10 feet in the area irrigated east of the San Joaquin River. North of the Tuolomne River the depth to ground water for a considerable portion of the area is from 10 to 50 feet and from 50 to 100 feet near the foothills. Pumping lifts average 35 feet in San Joaquin County, 57 feet in Stanislaus County, and 92 feet in Contra Costa County.

The extent of interest in the Water Facilities Program for developing ground water in this area is not apparent, as there were no applications in the hands of the Farm Security Administration at the time field investigation was made. Extreme caution should be observed in the matter of drilling for water in Contra Costa County especially when the site of the proposed well is nearer the foothills than the River. Nor should the rolling land near the foothills in the other two counties be expected to offer very favorable opportunities for development of irrigation wells. It is recommended that approval of requests made by the Farm Security Administration clients be generally limited to those from farmers operating on the better lands on the Valley floor, where pumping lifts are lower, the lands to be served are better and the cost of water reasonably low.

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